STATUS REPORT ON METRIC TRANSITION

(June 30, 1992)

National Aeronautics and Space Administration

I. INTRODUCTION AND SUMMARY

This report from the National Aeronautics and Space Administration (NASA) describes the status and outlook for NASA's metric transition as of June 1992. The report fulfills the special report requirement of Executive Order 12770 and follows guidelines approved by the Interagency Council on Metric Policy (ICMP) for reporting to the Secretary of Commerce. The guidelines require identification of agency program elements and supporting activities, specific types of status and descriptive information, and recommendations to remove identified barriers to metric transition.

This report describes NASA's metric transition in terms of seven major program elements. Six are technical areas involving research, technology development, and operations; they are managed by specific Program Offices at NASA Headquarters. The final program element, Institutional Management, covers both NASA-wide functional management under control of NASA Headquarters and metric capability development at the individual NASA Field Installations. This area addresses issues common to all NASA program elements, including: Federal, state, and local coordination; standards; private industry initiatives; public-awareness initiatives; and employee training. The concluding section identifies current barriers and impediments to metric transition; NASA has no specific recommendations for consideration by the Congress.

The activities described in this report are based on the Metric Transition Plan approved by the NASA Administrator on February 20, 1992. The Plan summarizes the individual metric transition plans developed by NASA Program Offices and reflects assessments of metric potential for current programs and projected new starts through the year 2000. Following completion in 1995 of internal initiatives to build metric capability, NASA should be able to use the metric system for research and new development programs if the required external support capabilities from industry are available. Allowing 3 additional years to complete development of programs based on the inch-pound system, all new programs should be using the metric system by 1998 except where directly related to past inch-pound programs. To minimize costs, disruptions, and risks, NASA will allow continued use of the inch-pound system by programs initiated before issuance of NASA's metric policy in 1990.

II. PROGRAM ELEMENTS

A. OFFICE OF SPACE FLIGHT

1. **Program Element Description.** The Office of Space Flight (OSF) performs missions involving crew-tended vehicles. These missions support NASA's goals to expand human presence in space and use the space environment to conduct scientific studies. The Space Shuttle (Orbiter, External Tank, Solid Rocket Motor, and Main Engine) is NASA's only current capability for transporting humans into space. The Space Shuttle is operational, although NASA is developing replacement hardware, such as the Advanced Solid Rocket Motor and new computers, to extend system capability and lifetime.

2. **Support Activities.** Standards, procurement, supply and equipment management, and personnel training are key support activities for this operational program element. It is essential that these activities and the program they support both use the same system of measurement. Facility construction and data systems are also key activities; they require only a common measurement system for interfacing with the program element they support, but can be performed in either measurement system.

3. **Measurement Sensitivity.** This program element and its key support activities are measurement-sensitive.

4. **Conversion Status and Sensitivity.** OSF approved a metric transition plan in April 1991. Space Shuttle hardware in inventory or in production uses the inch-pound system. Soft conversion for existing inch-pound Space Shuttle elements is impractical from the cost standpoint and undesirable from the safety/risk standpoint. Newly developed replacement hardware will be inch-pound to ensure compatibility with existing hardware.

Accommodation of metric payloads by (existing) inch-pound systems is NASA policy. Drawings of most Space Shuttle payload interfaces already state dimensions in both inch-pound and metric units, so metric payloads can be accommodated. Metric dimensions will be added to other interfaces when needed for metric payloads.

The European Space Agency (ESA) developed Spacelab for the Shuttle Orbiter using hard metric units. ESA, Germany, and Japan sponsored Spacelab missions with hard metric payloads. Several other nations have sponsored individual instruments that were metric designs. In current practice, interfaces with dual units accommodate inch-pound U.S. payloads, but evolution to hard metric units is possible.

5. **Transition Timetable.** There will be no conversion of the Space Shuttle and ground systems to metric units. The existing assets will be maintained and operated indefinitely; therefore, OSF will use the inch-pound system for the Shuttle beyond the year 2000. Metric payloads can be accommodated now.

B. OFFICE OF SPACE SYSTEMS DEVELOPMENT

1. **Program Element Description.** The Office of Space Systems Development (OSSD) develops new systems to support humans in space and new launch vehicles. The OSSD Space Station Freedom Program will establish a crew-tended laboratory, leading to permanent human presence in space. Future OSSD development programs are the New Launch System (NLS) and Assured Crew Return Vehicle (ACRV). The NLS is a joint program with the Department of Defense (DoD) to develop a next-generation launch vehicle that can be upgraded to carry humans to space. The ACRV will be a basic reentry vehicle that will provide an independent, emergency option for returning the Space Station crew to Earth.

2. **Support Activities.** Standards, procurement, supply and equipment management, and personnel training are key support activities for hardware development programs. It is essential that these activities and the program they support both use the same measurement system. Facility construction and data systems are also key activities; they require only a common measurement system for interfacing with the program they support.

3. **Measurement Sensitivity.** This program element and its key support activities are measurement-sensitive.

4. **Conversion Status and Sensitivity.** The OSF metric transition plan approved in April 1991 addresses the OSSD development programs. Space Station Freedom will be a hybrid system because it will contain both inch-pound and metric hardware. The foreign-built elements (such as the ESA and Japanese modules) will be metric and, according to a decision made in February 1987, the NASA-built elements will be inch-pound. (Space Station entered Phase C before NASA policy required use of the metric system by new programs.) Space Station interfaces, especially for payloads, generally express dimensions in dual units (both inch-pound and metric units) to accommodate future hardware built with the metric system. The NLS and ACRV programs are candidates for use of the metric system of measurement; detailed evaluations are underway.

5. **Transition Timetable.** Conversion of Space Station to the metric system would be impractical and costly. All Space Station elements now in development should be launched by the year 2000. After that date, the metric system may be used for design and development of new hardware elements. Maintenance and production of direct replacement hardware for the Space Station is expected to use the units of the original hardware; i.e., inch-pound for U.S. elements and metric for those built by international partners. For continuity, Space Station will use the inch-pound system for operational support beyond the year 2000.

C. OFFICE OF SPACE SCIENCE AND APPLICATIONS

1. Program Element Description. The Office of Space Science and Applications (OSSA) plans, directs, and executes NASA programs that use the space environment to: conduct scientific studies of the universe, understand the Earth as an integrated system, develop a basis for solving practical problems on the Earth, and provide a research base supporting human presence in space. From commercial sources, OSSA obtains expendable launch vehicles (ELVs) and upper stages for launching automated spacecraft.

The OSSA pursues an integrated programmatic approach encompassing ground-based laboratory research; suborbital flights on airplanes, balloons, and sounding rockets; experiments conducted on Shuttle/Spacelab and Space Station Freedom; and automated Earth-orbiting and interplanetary spacecraft. Currently, the Advanced X-ray Astrophysics Facility (AXAF), Cassini, and the Earth Observing System (EOS) are the major OSSA development programs. Ongoing OSSA development activities also include Spacelab experiments that will fly in 1992 and beyond, Explorers, and small satellites.

Major OSSA initiatives planned for the future include the Space Infrared Telescope Facility (SIRTF), the Stratospheric Observatory for Infrared Astronomy (SOFIA), and the Orbiting Solar Laboratory (OSL). OSSA expects these programs to be approved for development by FY 1998. Additionally, a new class of "intermediate" missions will be initiated in FY 1994. An augmentation to the Explorer program will provide a series of small, university-developed satellites. Many Space Station experiments will be developed by OSSA.

2. Support Activities. Standards, procurement, supply and equipment management, and personnel training are key support activities for scientific research and hardware development programs. It is essential that these activities and the program they support both use the same system of measurement. Facility construction and data systems are also key activities; they require only a common measurement system for interfacing with the program they support.

3. Measurement Sensitivity. This program element and its key support activities are measurement-sensitive.

4. Conversion Status and Sensitivity. The OSSA metric transition plan was approved in September 1990 and updated in April 1992. Scientific publications and procurements now use the metric system. Three major development projects, AXAF, Cassini, and EOS will use hybrid systems. OSSA plans to develop all satellites and instruments initiated after 1992 using the metric system unless a waiver is requested and approved. Some near-term waivers are expected because of strong dependence on "inherited" designs (i.e., previously developed or derivative) designs. Waivers were approved for the Advanced Composition Explorer and the NOAA-N satellite, which is a copy of an existing spacecraft to be built by NASA for the National Oceanographic and Atmospheric

Administration. Both systems will use existing or derivative inch-pound designs and, in the first case, existing inch-pound hardware. The SIRTF telescope, instruments, and spacecraft systems will be metric. The SOFIA telescope and instruments will be metric, except for the aircraft systems. The OSL will have metric instruments, although the spacecraft will be hybrid due to inherited inch-pound hardware. New "intermediate" missions, university-developed satellites, and initial Space Station Freedom experiments will be developed using the metric system. Existing U.S. commercial ELVs use the inch-pound system.

5. **Transition Timetable.** By 1998, most inch-pound hardware should be launched and the metric system should be used for all new hardware design and development. Use of the inch-pound system will continue as existing hardware is reflown (e.g., Spacelab instruments) or copied for new missions. OSSA will use the inch-pound system for on-orbit maintenance of the existing Hubble Space Telescope.

D. OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

1. **Program Element Description.** The Office of Aeronautics and Space Technology (OAST) conducts an Aeronautics Research and Technology program for civil, commercial, and military aircraft. This program provides a foundation of advanced technology upon which U.S. industry can maintain a competitive position in global aviation markets. The program develops, operates, and maintains unique national laboratories and facilities; it also addresses critical barriers to technology introduction.

The OAST Space Research and Technology program advances technologies for future space missions and strengthens U.S. industrial and academic engineering and research capabilities. The program provides near-term and long-range support for space and Earth science missions, space transportation systems, utilization of Space Station Freedom, ground and space operations, and human solar system exploration missions.

With DoD, OAST funds technology development for the National Aero-Space Plane (NASP). The stated goal for NASP is a single-stage-to-orbit vehicle. During its current technology phase, the program is advancing technology in key areas such as propulsion, materials, structures, and computational sciences.

2. **Support Activities.** Standards, procurement, supply and equipment management, and personnel training are key support activities for applied research and technology development programs. It is essential that these activities and the program they support both use the same system of measurement. Facility construction and data systems are also key activities; they require only a common measurement system for interfacing with the program they support. Tools, instruments, and measuring devices for safety monitoring functions should use the same system of measurement.

3. **Measurement Sensitivity.** This program element and its key support activities are measurement-sensitive.

4. **Conversion Status and Sensitivity.** OAST approved a metric transition plan in July 1991. Hardware designs, research reports, and engineering publications currently use the inch-pound system. A multi-project waiver of indefinite duration (with certification every 3 years) will be prepared for the Aeronautics Research and Technology program because the inch-pound system is the international standard for research, production, and operations in the aircraft industry. NASP also may require a waiver because the aeronautics industry uses the inch-pound system. The Space Research and Technology program uses the inch-pound system. Because future NASA missions will use the metric system, supporting projects in the OAST Space Research and Technology program will use the metric system.

5. **Transition Timetable.** NASA is a source of information for the aeronautics industry, rather than a major customer. Therefore, the NASA aeronautics program cannot change to metric units without a previous industry commitment; at present, there are no prospects for such a change. Through advisory committees and other liaison with the aeronautics industry, OAST is monitoring industrial plans for metric conversion. At this time, the industry has not established a specific date for completing metric transition. Operation of existing ground systems (especially wind tunnels) will use inch-pound units for several decades before needing replacement. The measurement system will be selected when new facilities are built.

The decision to proceed with Phase Three of NASP, which includes the design, construction, and flight test of a research vehicle, is scheduled for 1993. NASA and DoD will make the decision on metric system use at that time.

E. OFFICE OF SPACE COMMUNICATIONS

1. **Program Element Description.** The Office of Space Communications (OSC) is responsible for key communications, mission control, and data management systems. OSC has many ground facilities and operates the Tracking and Data Relay Satellite (TDRS) system. Four of the seven satellites are now operational; one was lost in the Challenger accident. The next TDRS launch is scheduled in December 1992; the seventh is in production. TDRS II is a new program intended as a next-generation replacement for the current system.

2. **Support Activities.** Standards, procurement, supply and equipment management, and personnel training are key support activities for hardware development and operational programs. It is essential that these activities and the program they support both use the same system of measurement. Facility construction and data systems are

also key activities; they require only a common measurement system for interfacing with the program they support.

3. **Measurement Sensitivity.** This program element and its key support activities are measurement-sensitive.

4. **Conversion Status and Sensitivity.** The existing TDRS spacecraft are of nearly identical designs using the inch-pound system. NASA expects TDRS II will be a hybrid system that may use metric units for new elements but would retain inch-pound units for elements based on inherited designs. OSC will prepare a waiver for use of inherited design elements developed with the inch-pound system.

5. **Transition Timetable.** Existing OSC ground systems such as tracking stations will operate with inch-pound units for several decades before needing replacement. Most subsystems on the TDRS II spacecraft bus will be based on existing designs that use the inch-pound system. The payload will include some new hardware that could be metric, but full transition of the TDRS space segment to metric will not occur until TDRS II is replaced (at least a decade away).

F. OFFICE OF EXPLORATION

1. **Program Element Description.** The Office of Exploration manages the Space Exploration Initiative (SEI). The long-term goal of SEI is a permanent human presence on the Moon and human exploration of Mars. The near-term plan includes deployment of automated spacecraft, known as precursor missions, to the Moon and Mars and establishment of the First Lunar Outpost. The SEI program currently focuses on developing the system definition, technology, and cost-estimating base needed to proceed with the planned human exploration of the Moon and Mars.

2. **Support Activities.** Standards, procurement, supply and equipment management, and personnel training are key support activities for research and technology development programs. It is essential that these activities and the program they support both use the same system of measurement. Facility construction and data systems are also key activities; they require only a common measurement system for interfacing with the program they support.

3. **Measurement Sensitivity.** This program element and its key support activities are measurement-sensitive.

4. **Conversion Status and Sensitivity.** SEI uses the metric system for many technical reports and publications. The precursor missions will make extensive use of existing inch-pound hardware designs. Longer range programs will use the metric system, unless

approved waivers allow use of inherited hardware designs. The first automated precursor, the Lunar Resources Orbiter, has an approved waiver.

5. **Transition Timetable.** Although the first automated missions may require waivers, after 1995 the new development programs are expected to use the metric system.

G. INSTITUTIONAL MANAGEMENT

1. **Program Element Description.** Metric transition for institutional management includes both NASA-wide functional management supervised by NASA Headquarters and development of capabilities by individual NASA Field Installations. This program element provides the overall management for the support activities used by the other program elements. Specific functional support areas addressed in the NASA Metric Transition Plan are standards, supply and equipment management, public affairs, education, and small business initiatives. Other areas for which the report guidelines requested comment are procurement, grants, budget and legislative affairs, and data systems. Field installation capability development is discussed separately.

2. **Support Activities.** Institutional management involves the same support activities as research and technology development programs, although the balance shifts toward commercially available items rather than development of unique systems. Thus, standards, procurements, personnel training, facility construction, supply and equipment management, and data systems are key activities supporting this program element.

3. **Measurement Sensitivity.** The principal measurement-sensitive support activities of this program element are standards, construction, supply and equipment management (including logistics), training, education, public affairs, and small business initiatives. The NASA Metric Transition Plan includes specific tasks for these activities. Although other areas such as publications, budgetary and legislative affairs, procurements, grants, and data systems may involve measurement-sensitive information, they do not require separate transition tasks to support a major program element using the metric system.

4. **Conversion Status and Sensitivity.** In October 1991, the Office of Management Systems and Facilities developed a transition plan for training, supply and equipment management (including logistics), and facilities engineering. Institutional management currently uses the inch-pound system, but will introduce both "hard" and soft metric units as such items become available from suppliers. When functional activities support programs using both inch-pound and metric units, they will maintain capabilities in both measurement systems or use soft conversion between them.

5. **Transition Timetable.** The NASA Metric Transition Plan provides an implementation schedule for specific areas. Overall, NASA should be able to use the

metric system for all technical support operations, administrative functions, and external activities by the end of 1995.

6. **Federal, State, and Local Coordination.** NASA conducts cooperative development programs with other Federal agencies. For example, the NLS and NASP programs involve the DoD; NASA also develops weather satellites in cooperation with NOAA. In each case, the partners will make a joint decision on metric system use for the bilateral program.

NASA has no regulatory or entitlement grant programs that require large-scale, continuing interactions with state and local governments.

NASA actively participates in government-wide metric planning through the Interagency Committee for Metric Policy and its working arm, the Metrication Operating Committee (MOC). NASA is an active member of the MOC Steering Committee that develops and assesses government-wide transition activities, and the four MOC subcommittees: construction, education, procurement, and metric practice.

Continuing interaction between NASA and the Department of Defense (DoD) on metric transition activities has involved cooperation on overall program planning, specifications, and standards.

Except for direct support of technical programs (described in previous sections) or cooperative programs through the MOC subcommittees, none of these activities require separate transition initiatives.

7. **Standards.** For NASA's development programs, cost-effective design, fabrication, and operation of aerospace systems depend on timely availability of metric standards, specifications, and processes. NASA develops some standards internally, or in cooperation with other Federal organizations (e.g., DoD), and others in cooperation with nongovernment standards organizations.

NASA presently uses the inch-pound system for hardware and for specifications, standards, and procedures. To use the metric system, NASA's development programs need metric versions of these documents.

The Kennedy Space Center has completed a review of internally developed standards and specifications, identified those that require metric versions, established a conversion plan, and begun conversion of the first documents. A follow-on activity will identify commonly used standards from outside sources and priorities for conversion to the responsible organization. Initial changes to NASA standards will use soft conversion to maintain continuity during the transition period. This activity will be extended NASA-wide by the end of 1992. Closely related to conversion of standards will be the establishment of common metric practice guidelines. Identification of required metric

standards also will be highlighted as an early planning activity for new flight programs and projects.

Specifications and standards are an essential activity for pilot projects, started in 1992, that will produce aerospace fasteners and fluid fittings in metric sizes. The metric fastener program conducted through the Marshall Space Flight Center is examining Agency needs for space quality parts, and reviewing the suitability of available national metric standards with the sponsoring organizations. Selected parts will be fabricated, qualified, and used on NASA pilot programs. The Kennedy Space Center is conducting a similar program for metric fluid fittings used on ground (launch) facilities.

8. **Private Industry Initiatives.** Private industry is a key partner with NASA in both hardware development and functional support programs. NASA cultivates and maintains strong industry relationships, especially with small, disadvantaged businesses.

Industry capabilities for supporting metric transition were an early focus of NASA planning. In 1990, NASA performed a special study to assess readiness of the aerospace industry to support metric use and to define transition issues. Also in 1990, NASA surveyed small machine shops--an important small business sector, to assess metric capabilities and experience.

In 1992, the NASA Small Business Program Office began including information on metric transition in its workshops with small businesses seeking opportunities with NASA. The Office of Safety and Mission Quality has developed a computer survey program to help small businesses determine if their quality systems can meet NASA requirements. It will be modified to collect information on metric capabilities, experience, and interests on a broader scale.

Similar to other Federal agencies, NASA's facility and construction needs depend on commercial practice. NASA has actively participated in the MOC Construction Subcommittee, working closely with industry groups to identify metric transition requirements and industry preparedness. The Subcommittee has targeted January 1994 as the date by which the product specifications and design standards needed to submit metric construction bids will be available to industry. Under sponsorship of the NASA Headquarters Facilities Construction Office, each NASA Installation has identified at least one potential metric construction project; the aggregate value of the potential projects is $14M. Detailed preparation for the projects began in July 1992, including the first presentation of a commercially developed training course for facility construction.

Section 7, "Standards," described an initiative to produce standards and hardware for space-qualified piece parts. Those parts will be produced commercially; two objectives of the projects are to assure qualified U.S. sources for required parts and provide some focus for aggregating demand.

9. **Public-Awareness Initiatives.** NASA supports mathematics, science, and technology education from grade school to graduate school through the Education Division. NASA has developed many metric instructional materials such as "Space Mathematics" and "Metrics in Space." According to a October 1991 decision, all new educational materials will be developed using only the metric system.

The Office of Public Affairs distributes information about NASA programs and results of NASA research both to the general public and internally within NASA. The Office has begun preparation for the inclusion of metric units (initially as dual units) in its media materials as required by NASA programs by the end of 1992.

External public affairs materials currently use the inch-pound system. Experience indicates continuing reluctance of external news media to use the metric system because of unfamiliarity with the system. Public Affairs will work with the media to introduce metric units in materials describing NASA programs.

Additionally, the Office of Public Affairs is producing a metric poster to foster positive attitudes toward metric use. The poster is based on the digital nature of the metric system and uses the theme, "METRIC IS A PERFECT 10."

10. Employee Training. Employees receive information about NASA activities through television, the NASA Magazine, the Administrator's Weekly Newsletter, and field installation newsletters and bulletins. To build awareness, articles on metric transition have appeared in field installation newsletters, orientation classes were held, and videotapes were broadcast through internal TV networks. Most of the orientation and training materials were obtained from private sector trainers, although two NASA Field Installations have produced internal guides to conversion between measurement systems.

Planning is underway to establish of NASA-wide training courses to meet varied needs from the general familiarity required by administrative support personnel to the operational capability required for engineering staff. Private sector experience indicates that general education takes 1 or 2 days. Common modules will be used wherever practical to avoid unnecessary duplication in course development. NASA will assess training programs developed by other Federal agencies such as the General Services Administration (GSA). Information about the metric system will be incorporated into professional development, skills upgrade, and apprentice programs.

11. Field Installation Capability Development. Supplementing the NASA-wide activities described in previous sections, each NASA Field Installation must prepare its institutional capabilities for use of the metric system. To date, five of the nine major NASA Field Installations have completed internal surveys to assess current capabilities and identify capabilities required. In general, the studies identified a need for considerable support in areas such as equipment acquisition, supply development, and training.

Some initiatives are underway, such as for awareness and training, but acquisition of tooling and equipment must be phased over several years. Most contemporary instruments for calibration and metrology have a dual measurement capability. Similarly, modern machine tools often have digital control capabilities in both measurement systems. Future tooling and equipment will have dual capabilities.

The Program Offices at NASA Headquarters with responsibility for institutional support and oversight (OSF, OAST, and OSSA) have asked Field Installations to implement metric transition with available resources. Where practical, metric capability development will be achieved within normal maintenance and replacement budgets and schedules to minimize additional transition costs. Preliminary estimates suggest that without acceleration of institutional funding, acquisition of full capability could slip to 1997.

NASA Field Installations play a vital role in identifying practical barriers to metric transition and developing detailed program plans. During 1991, the Langley Research Center used metric units for the preliminary design of a small technology experiment for a Space Shuttle payload. Aside from modest increases in mechanical design time, not unexpected for "first time" use of new (i.e., metric) procedures, the only continuing problems identified were availability of metric piece parts, specifically threaded fasteners, and availability of standards for materials properties in metric units. The activities described above address these issues. Other Field Installations are working to identify metric pilot projects. For at least one major program, preliminary studies have involved interactions between government and contractor teams.

III. CONCLUSIONS

A. CURRENT BARRIERS AND IMPEDIMENTS

Significant barriers to metric transition remain; however, removing the barriers is more a function of time and funding than difficulty. The identified barriers and impediments are described below.

1. **Existing Capital Assets.** NASA has a very large investment in major flight and ground systems designed using the inch-pound system, including the Space Shuttle, Space Station Freedom, launch facilities, and wind tunnels. Soft metric conversion is impractical because of safety and cost considerations. Therefore, NASA will continue using the inch-pound system for operational programs, but soft conversion at user interfaces should be adequate to accommodate new metric designs.

2. **Industry Transition.** Industry provides the hardware and support services for most NASA programs. Few commercial sources provide supplies and equipment in metric sizes or produce metric hardware that meets aerospace requirements. Because NASA is not a major customer in any market except the space industry, the ability to influence the market through demand supporting NASA contracts is limited. The aerospace industry as a whole has not been responsive to metric transition, primarily because the world standard for aircraft remains inch-pound. That could result in NASA requests for metric hardware becoming "special orders" only, with possible cost differences and safety concerns when both measurement systems are in use.

3. **Cost of Institutional Transition.** Field installation studies to date have suggested there are real costs associated with transition, such as purchase of equipment, revision of procedures, and development of supply sources. While much of the required metric capability can be acquired in normal replacement cycles, extra costs for requirements that do not improve the performance or safety of programs may suffer from lower funding priority, resulting in program stretchout.

B. RECOMMENDATIONS

NASA does not have any recommendations requiring additional legislative action by the Congress. Areas requiring action are generally within the scope of the defined NASA Metric Transition Plan.